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Characterisation of apatite and secondary phosphate minerals in Sukulu phosphatic soil, Uganda

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ABSTRACT

The Sukulu deposits were first discovered to be of economic significance in the 1950's which is a ring carbonatite complex of 5 km in diameter. Although the original carbonatite has been considered subeconomic, leaching and watering of the rock has resulted in over 200 million tons of residual soil, rich in apatite, magnetite and other heavy minerals. The sample, in general, made up of fines and friable concretions heavily coated with ferruginous and limonitic materials. The X-ray powder diffraction of the soil indicates the presence of apatite as a dominant, primary phosphatic phase, the cell parameters of which are almost in between pure fluor and hydroxyl–apatite end members. Refractive index (R..I.) study, geochemical analysis and X-ray mineralogy indicate that the apatite is of mixed composition with fluorapatite structure and bear a close resemblance to that of apatite from Beldih, Purulia district, West Bengal. Crandallite is the major secondary phosphatic phase associated with goyazite and gorceixite. Magnetite (martitised along the cleavage plane and fracture plane), hematite, quartz, limonite and maghemite are the major gangue minerals. Ferrocolumbite, pyrochlore, zircon and limonite are the heavy minerals that are present in the sample. The liberation study shows that most of the composite grains (iron minerals + silicates) are concentrated above 100 mesh fractions while most of the free apatite are within the size range of 100 to 200 mesh.

INTRODUCTION

Apatite is the principal phosphorus containing mineral in carbonatites, and in southern and eastern Africa such occurances were becoming of increasing economic importance[1]. Deans[2] has presented an excellent summary of several such deposits in which apatite may comprise 90% of certain ring dikes.

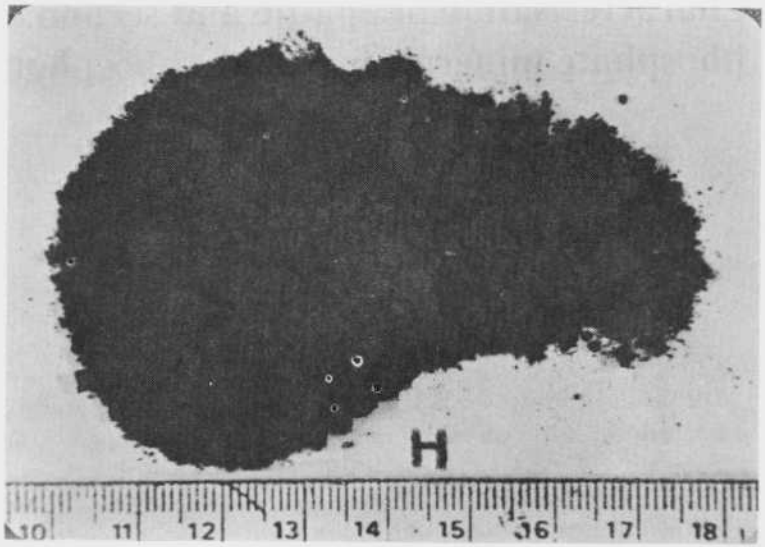

Plate 1 : Macrophotograph of as-received sample.

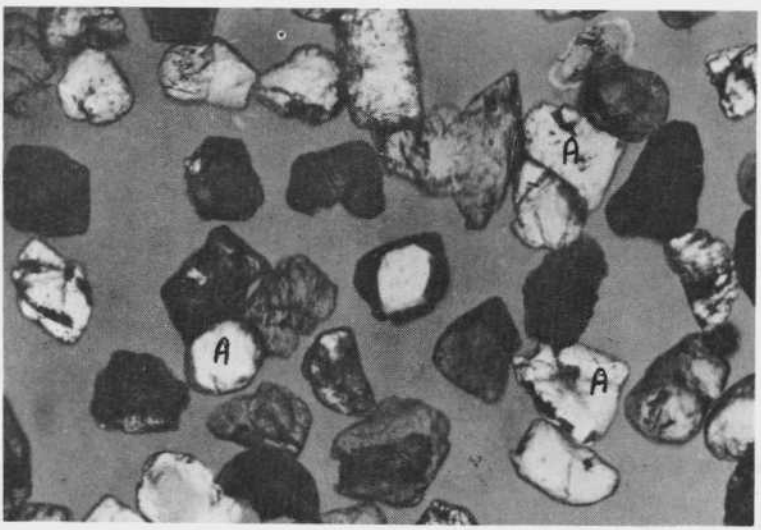

Plate 2 : Bromoform heavy fraction in immersion liquid showing enrichment of apatite (A) with traces of other heavy minerals. (X 350), Nicols Crossed.

The Sukulu deposits were first discovered to be of economic significance in the 1950's, and in 1965, a small plant for recovering apatite was put into production. The Sukulu deposits, situated in a small carbonatite complex are approximately 4 km. in diameter, were mined for apatite until the late 1970's, when all operation ceased. An estimated 200 million tonnes of average grade 13% P_2O_3 residual soil obtained from weathering and leaching of subeconomic carbonatite rocks[3].

The as received sample is reddish-brown in colour consisting mainly of fines and friable concretions with extensive coating and staining of ferruginous matter (Plate 1).

EXPERIMENTAL

Representative sample was prepared by conning and quartering followed by washing, hand scrubbing and separation of slime (–325 mesh) by wet screening. Later, sand and slime were dried and sizing of sand was done by screening. Hand magnetic separation was carried out made for each sand fraction and heavy liquid separation of non-magnetics was performed using bromoform. Optical microscopy and X-ray spectroscopy studies of the head sample, concentrate and slime were carried out.

The sand obtained by washing and hand scrubbing was approximately 35% by weight, which after sizing and magnetic separation showed most of the non-magnetics were within the size range of 60 to 200 mesh. The non-magnetic fractions showed concentration of heavy minerals within the size range of 60 to 200 mesh. The modal analysis of heavy fractions showed an enrichment of apatite, within the size range of 60 to 200 mesh (Table 1).

RESULTS AND DISCUSSION

Microscopic studies of sand show that most of the grains are discrete in nature, elongated, subangular to subrounded in shape. Heavy liquid separation by bromoform (sp. gravity 2.88) indicates that heavies are enriched in apatite and opaques (plate 2) while siliceous (quartzo–feldspathic) minerals are predominant in the lighter fraction. All the minerals show varying proportion of staining and coating as a result of weathering and alteration of phosphatic soil. This is more prominent in coarser grains while finer apatite grains are comparatively free from staining and alteration. Non-magnetic heavy fraction dominantly made up of apatite with minor proportions of zircon, anatase, tourmaline, biotite, amphibole, columbite-tantalite etc.

Magnetic fraction mainly consists of magnetite (martitised) and hematite in association with minor proportion of goethite, limonite, ilmenite, locked silicates

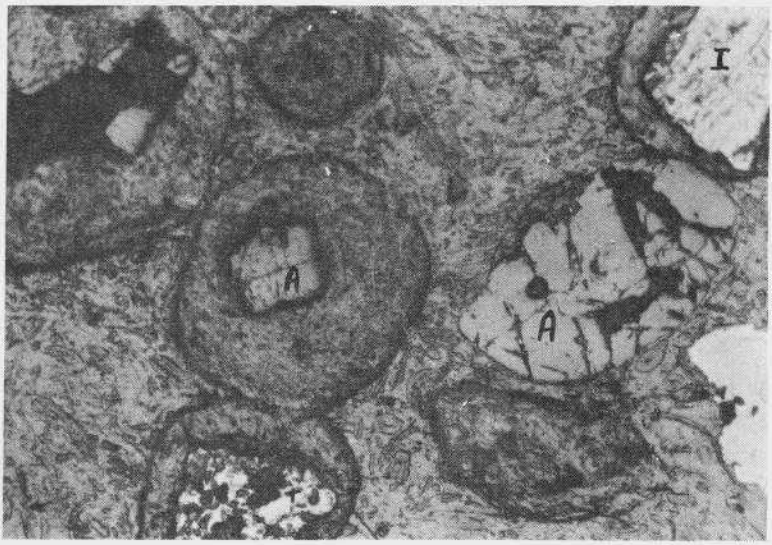

Plate 3 : Microphotograph of apatite (A) and iron oxide (I) entrapped within limonitic rim, reflected light, (X 350), Nicols not crossed.

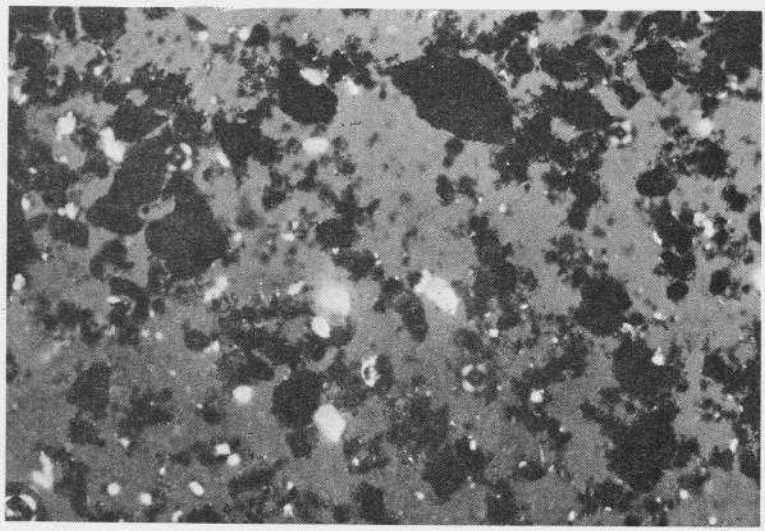

Plate 4 : Microphotograph of slime showing the presence of apatite and silicate (white) within iron oxide matrix, plane polarised light, (X 350).

Table 1 : Modal analysis of magnetic fraction

Mineral Association	Size fractions in mesh								
	+28	+35	+48	+60	+100	+150	+200	+250	+325
	Volume percent								
Iron oxide with & without limonite rim	92.7	91.4	86.0	85.6	83.8	74.4	86.4	77.9	71.9
Iron oxide with non-metallic grain (mainly apatite and quartz)	5.1	4.3	3.3	2.1	0.6	-	-	-	-
Non-metallic minerals with limonite rim	1.2	1.9	5.3	3.1	1.8	1.0	0.4	-	-
Iron oxide mineral with inclusions of non-metallic minerals	1.0	1.5	2.1	1.0	0.8	0.5	-	0.1	-
Limonitc Oolites	-	0.9	3.3	8.2	13.0	24.1	13.2	22.0	28.1

and apatite (plate 3). Martitisation in varying degrees are documented along the exolution lamellae. Alteration of magnetite to goethite are mainly noted along the fracture plane of the magnetite. Apatites in magnetic fraction mostly occur in intergranular and interstitial spaces as composite grains or inclusion.

The liberation study shows that most of the composite grains (iron oxide + silicates) are concentrated above 100 mesh fractions while most of the free apatite within the size range of 100 to 200 mesh. Grinding of composite grains above 60 mesh likely to contribute free apatite grains. The slimes are mostly of limonitic materials in which apatite, silica and magnetite occur as discrete phases as well as composite grains (plate 4).

X-ray powder diffraction spectra of the as received sample, concentrate and slime (Figs. 1 to 3) show that fluor-hydroxyl apatite is the dominant apatite mineral. The cell parameters of the apatite mineral (a = 9.392 to 0.01 A° and c = 6.911

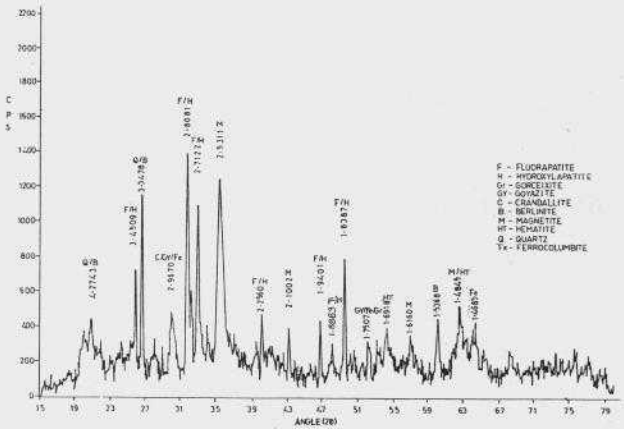

Fig. 1 : X-ray powder diffraction pattern of as received sample (Uganda Phosphatic Soil).

+ 0.018 A°) are almost in between pure fluor apatite and hydroxyl apatite end members. This bears a close resemblance to the apatite from Beldih area[4], Purulia District, West Bengal. It can be attributed for if some fluorine (F) is substituted by OH^- and $C1^-$ in fluorapatite lattice[4]. Crandallite is the another major phosphate mineral associated with goyazite, gorceixite, berlinite, and brushite in different proportion. Magnetite, maghemite, hematite, quartz and limonite are the major gangue minerals. Ilmenite, zircon, ferricolumbite/pyrochlore are the accessory phases. The mineralogy of the concentrate and slime are similar to that of as received sample with proportion of ore minerals and gangues varies substantially, i.e., ore minerals are much more in the concentrate and considerable in the slime.

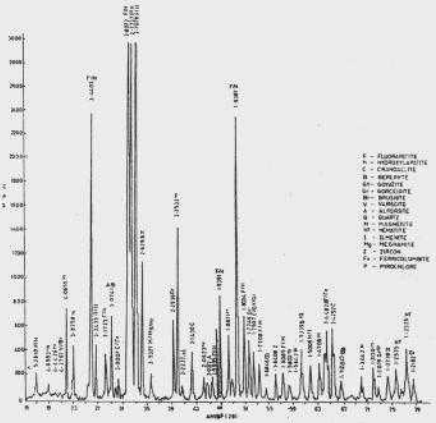

Fig. 2 : X-ray powder diffraction pattern of phosphate concentrate.

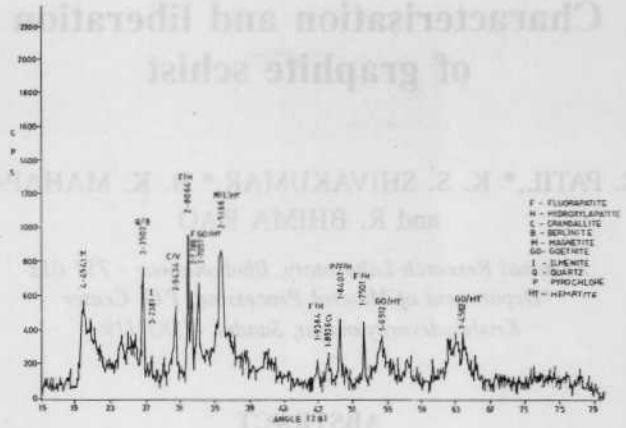

Fig. 3 : X-ray powder diffraction pattern of slime.

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